Adequate speculation, excessive speculation and crude oil futures price volatility

1. Introduction

A notable characteristic of crude oil prices over the last four years is their increased volatility. For example, the spot price of crude oil rose from a low of \$51 a barrel on 22 January 2007 to a peak of \$145/barrel on 14 July 2008, and, subsequently, dropped to a low of \$30/barrel on 23 December 2008. The volatility in crude oil prices has had devastating impacts on industries such as, for example, the airline industry. Jet fuel prices are highly correlated with crude oil prices. Airlines which failed to hedge when prices were low suffered losses when prices subsequently rose. Airlines which hedged when prices were high, suffered losses on their hedges when fuel prices later dropped. The volatility in crude oil spot prices could be due to the transmission of increased volatility in crude oil futures prices which in turn may be due to excessive speculation in the crude oil futures market. In this paper, we investigate the relationship between speculation in the New York Mercantile Exchange (NYMEX) West Texas Intermediate (WTI) crude oil futures contract and the volatility of the futures price.

Excess volatility in the crude oil futures market may be undesirable for two reasons. First, as previously mentioned, volatility in the crude oil futures market may be transmitted to the spot market for crude oil, and the resulting spot market volatility may have an adverse effect upon the economy. Berkovitz (2009) examines the legal history of position limits and hedge exemptions in the futures markets from the time that the Commodity Exchange Act (CEA) was enacted in 1936. The basic idea behind the CEA is that excessive speculation in any commodity futures contract which causes extreme volatility in the price of the commodity is a burden, and therefore the Commodity Futures Trading Commission (CFTC) should establish speculative position limits to make sure that this undue burden did not arise. Cooper (2008) points out that if the volatility of crude oil prices is high, those who own the oil have to be paid higher prices to sell it at the current time, since there is an increased chance that the price would go higher and they would have lost out on a possible profit opportunity. Pindyck (2001) states that fluctuations in the price of a commodity, whether these are caused by fundamental factors such as supply and demand, or by speculation, would cause fluctuations in production and consumption of the commodity, as well as an increase in storage of the commodity by both producers and users, whose purpose is to hedge against the risk of running out of the commodity when it is needed.

Second, while a certain degree of volatility in the commodity price and the futures price are both necessary for a futures market to exist, increased volatility in futures prices beyond a certain level may harm the futures market's continuing viability. The increased volatility in the price of the NYMEX crude oil futures contract has been cited by several newspaper articles in October 2009, as the reason why Saudi Arabia decided to stop basing the price of crude oil for its U. S. customers on the NYMEX's WTI crude oil futures price, but instead, to use the Argus Sour Crude Index (ASCI) which was created by the U. K. company Argus Media, from January 2010 onwards. This decision could have caused a decrease in the liquidity of the WTI crude oil futures contract traded on the NYMEX. The CMEGroup, the parent company of the NYMEX, subsequently launched a futures contract on the ASCI on January 24, 2010 (CMEGroup (2010)).

Most previous studies on the effect of speculation in the crude oil futures market focused on the increase in the price of crude oil. Medlock and Jaffe (2009) show that the open interest attributed to non-commercials (traditionally viewed as speculators), trended up after the Commodity Futures Modernization Act (CFMA) of 2000 which essentially exempted the

InterContinental Exchange (an exchange with headquarters in the U. K.) from oversight by the CFTC and was accompanied by increases in oil prices. However, Pirrong (2009) criticizes the Medlock and Jaffe study on several aspects—lack of a reason for the relationship between speculative activity and increases in oil prices, the methodology (graphs rather than an analytical study), the necessity to address fundamental factors that would affect the price of oil, and the necessity to use a Granger causality approach to establish cause and effect. Masters and White (2008) argue that increases in the price of crude oil in the first 5 months of 2008 was caused by index speculators who "poured money" into the crude oil futures market, while the subsequent drop was caused by their retreat from the futures market when "Congress threatened action". They state that "If Congress acts to restrict speculation, then price volatility will be reduced…".

We make several contributions to the literature on the relationship between speculation and the volatility of the crude oil futures price. First, we extend previous research by Jiang and Shanker (2011) to define two innovative indices: 1) an index of adequate speculation, which measures the degree of speculation which is just sufficient to meet net hedging demand, and, 2) an index of excessive speculation, which measures the degree of speculation in excess of the amount that is necessary to meet net hedging demand, and we then estimate the relationship between these two measures of speculation and price volatility in the crude oil futures market.

If short (long) hedging equals or exceeds long (short) hedging, then our definition of net hedging demand is the excess of short (long) hedging over offsetting long (short) hedging contracts. In defining these indices, we explicitly address the fact that not all long (short) hedging contracts may offset short (long) hedging contracts. This is because short and long hedgers may differ on the duration, the size and the timing of their hedging positions in the futures markets. Keynes (1923) notes that producers of a commodity may want to take a short position in the futures market far ahead of the time when they expect production to be completed. Users or consumers of the commodity, on the other hand, who hedge by taking a long position in the futures market, may want to hedge over a shorter period of time, lifting the hedge when the purchase of the commodity in the spot market is completed. Hirshleifer (1990) notes that producers of commodities tend to be large enterprises and their short futures hedging position sizes are large, while there are generally many consumers of the commodity, whose individual consumption and therefore, long futures hedging positions tend to be small. In addition, fixed costs associated with using the futures market for hedging could discourage small consumers from entering these markets. Working (1960) notes that most long hedging is generally absorbed by short speculation, and Peck (1979-80) notes that short hedgers and long hedgers may differ on seasonal needs for hedging as well as on the timing and the duration of their hedges. Although it has been recognized by previous researchers that not all long (short) hedging contracts may offset short (long) hedging contracts, this has not been taken into account in previous estimates of excessive speculation. While Working's speculative index is an exception, in what follows, we explain why our indices offer improvements over his index both conceptually and analytically.

Working's speculative index T has been extensively used by previous researchers, including Peck (1980), and Hartzmark (1986), and continues to be extensively used, as in recent papers by Sanders et al (2008), and Du et al (2011). Working has made an enormous contribution to the study of futures markets. However, Jiang and Shanker point out that in deriving his speculative index, Working notes that while in a futures market with no long hedging, a speculative index could be estimated by the ratio of long speculation to short hedging, "If there is a purely logical reason for deducing how to write the formula for a speculative index for markets *with* long hedging, it escapes me". Jiang and Shanker note that in a market in which short hedging equals or exceeds long hedging, the required amount of long speculation is the excess of short hedging contracts over offsetting long hedging contracts. Hence long speculation in excess of this amount constitutes excess speculation. This provides a logical basis to estimate a measure of excessive speculation. In addition, as Working does, let us define the speculative ratio as the ratio of long (short) speculation to short (long) hedging, for a market in which short (long) hedging equals or exceeds long (short) hedging. Jiang and Shanker note that Working incorrectly assumed, on the basis of empirical results, that the intercept and slope of the line which relates the actual speculative ratio to the hedging ratio, should have a particular relationship, and derived his speculative index on the basis of this assumption. They provide a correction of his analysis.

Our index of adequate speculation is the ratio of net hedging demand, to the highest hedging demand (long or short). Hence, this is a measure of hedging pressure in a futures market. Hirshleifer notes that if there is an imbalance between the hedging pressures of producers and consumers, then speculators will have to be offered a price incentive to trade with the hedgers. The futures price should fall (rise) to induce speculators to take long (short) positions to satisfy net short (long) hedging demand. Hence we would expect that our index of adequate speculation would be positively related to the futures price volatility. Our index of adequate speculation is also the ratio of that portion of long (short) speculation which is just sufficient to meet net short (long) hedging demand, to total short (long) hedging. This may be regarded as the position of naïve speculators who stand ready to take positions opposite to those of hedgers, provide a service by doing so, and benefit from the compensation for this service.

Our index of excessive speculation is the ratio of long (short) speculation in excess of net short (long) hedging demand to total short (long) hedging demand, when short (long) hedging equals or exceeds long (short) hedging, or the ratio of offsetting speculative contracts to total short (long) hedging contracts. Working notes that an increase in the amount of "unneeded speculation" could be due to the entry of uninformed speculators or by an informed group of speculators with information which is being ignored by other informed speculators.

Previous researchers offer conflicting explanations of the effect of pure speculation upon price volatility. Friedman (1953) argues that rational arbitrageurs in currency markets would buy the currency when its price is too low and sell it when its price is too high, thus tending to stabilize its price. However, DeLong et al (1990) note that when noise traders drive an asset's price away from its fundamental value, rational arbitrageurs may be reluctant to enter the market, out of fear that the noise traders' beliefs and trades may move the price further away from its fundamental value. Therefore, we conduct an empirical analysis of the relationship between our indices of speculation and crude oil futures price volatility.

Second, we contribute to the ongoing debate as to whether market fundamentals or speculation is responsible for the run up in crude oil prices. While the Interagency Task Force concluded in 2008 that increases in the price of crude oil were due to market fundamentals, such as those that affect supply and demand, Davidson (2008) provides arguments that support the role of speculation. In his view, oil futures prices increased 86% while world demand increased 2%, indicating that it is not market fundamentals but speculation which has raised oil prices. Since it is easier to trade futures contracts rather than the spot commodity, the effect of changes in these fundamental factors may show up as increases in the volatility of the futures price. We consider the effect of fundamental factors such as those that should affect the supply and demand of crude oil by incorporating variables that proxy for these factors. The proxies for supply include the production of crude oil in the U. S., the stock of crude oil in the U. S. excluding that held in the Strategic Petroleum Reserve (SPR), the stock of crude oil within the SPR and the net imports of crude oil. The proxy for demand is the input of crude oil into refineries.

Third, we contribute to the literature on the causal relationship between speculative activity in futures markets and futures price volatility. Bryant et al (2006) investigate the causal effect of large speculator activity upon the futures price volatility in several different futures markets. Large speculator activity is defined as the sum of long and short contracts held by large speculators. They find that large speculator activity is unrelated to volatility for the crude oil futures contract. We use a Granger causality analysis to analyze the causal effect between our indices of speculation and the crude oil futures price volatility.

Fourth, we address the effect of policy changes that could have led to increases in crude oil prices and volatility. Cooper describes these policy changes. These are: the granting of exemption to the ICE from oversight by the CFTC and exemption to swap dealers from speculative position limits, the relaxation of rules for hedge funds by the CFTC, the relaxation of rules for banks by the Federal Reserve and granting of permission to the ICE to trade the WTI crude oil futures contract. Accordingly, we breakdown the overall period from March 21, 1995 through March 10, 2009 into five sub-periods, which correspond to a benchmark period and a period following each policy change, and analyze the relationship between speculation and crude oil futures price volatility for the different sub-periods.

In Section 2, we describe our indices of adequate speculation and excessive speculation. Section 3 describes our data, while Section 4 describes our methodology and provides our results. Our conclusions are provided in Section 5.

2. Our indices of adequate speculation and excessive speculation

We first explain Working's speculative index, and Jiang and Shanker's analysis of the speculation required and in excess of that needed to meet net hedging demand, and then describe our indices of adequate speculation and excessive speculation in detail.

2.1 Working's speculative index T

Working defines his speculative index as follows:

$$T = \begin{cases} 1 + \dfrac{SS}{HS + HL} \; if \;\; HS \geq HL \\ 1 + \dfrac{SL}{HS + HL} \; if \;\; HL \geq HS \end{cases} \tag{1}$$

Where *SS*=open futures positions of short speculators, *SL*=open futures positions of long speculators, *HS*=open futures positions of short hedgers and *HL*=open futures positions of long hedgers. Working details how he derived this index in the Technical Appendix to his paper. Defining the speculative ratio as equal to *SL/HS* (*SS/HL*) and the hedging ratio as *HL/HS* (*HS/HL*) when $HS \geq HL$ ($HL \geq HS$), he concludes that his empirical analysis of the relationship between the average speculative ratio and hedging ratio for eleven different futures markets indicated that the following relationship holds:

$$Speculative\ ratio = 1 + \alpha - (1 - \alpha) Hedging\ ratio \tag{2}$$

Therefore, he concludes that the parameter α could be used to describe the speculative characteristics of a market. Setting $T = 1 + \alpha$, Working used the identity $HS + SS = HL + SL$ and equation (2) to solve for the value of *T*. The result is equation (1). Note that in a market with no long hedging, the *T* index is essentially the ratio of long speculation to short hedging.

2.2 Jiang and Shanker's measure of excessive speculation

Jiang and Shanker note that they offer a logical measure of excessive speculation, which is based on a comparison of the required amount of speculation that is just sufficient to meet hedging demand, with the actual amount of speculation in a market, and further point out an error in Working's analysis. We explain their analysis in what follows.

2.2.1 Situation in which short hedging exceeds or equals long hedging

Suppose that $HS \geq HL$, HO represents offsetting hedging contracts, and $M=HO/HL$ represents the proportion of long hedging contracts which are offsetting hedging contracts. If long hedgers and short hedgers enter the market at the same time, and the size of their positions are equal, then all long hedging contracts are offsetting hedging contracts and M=1. If long and short hedgers enter the market at completely different times, then no part of long hedging contracts offset short hedging contracts and M=0. If some long hedgers enter the market at the same time as some short hedgers, some portion of long hedging offsets short hedging, so that $0 \leq M \leq 1$. The amount of long speculation SL_R which is required to meet net short hedging demand is given by:

$$SL_R = HS - M.HL \tag{3}$$

Dividing equation (1) throughout by HS, the required relationship between the speculative ratio and the hedging ratio in a futures market in which speculation is just sufficient to meet net hedging demand is given by:

$$\frac{SL_R}{HS} = 1 - M.\frac{HL}{HS} \qquad \text{if } HS \geq HL \tag{4}$$

Note, however, that the actual open interest of long speculative contracts SL_A is the sum of long speculative contracts which offset net short hedging demand $HS\text{-}M.HL$ and long speculative contracts which offset short speculation SO, as represented by the following equation.

$$SL_A = HS - M.HL + SO \tag{5}$$

Dividing equation (5) throughout by HS, the actual relationship between the speculative ratio and the hedging ratio is given by:

$$\frac{SL_A}{HS} = \frac{HS - M.HL}{HS} + \frac{SO}{HS} \tag{6}$$

Equation (6) reduces to:

$$\frac{SL_A}{HS} = 1 + \frac{SO}{HS} - M.\frac{HL}{HS} \tag{7}$$

Comparing the required speculative ratio of equation (4) with the actual speculative ratio of equation (7), Jiang and Shanker offer a measure of excessive speculation which equals:

$$MES = 1 + \frac{SO}{HS} = \frac{SL_A}{HS} + M.\frac{HL}{HS} \qquad \text{if } HS \geq HL \tag{8}$$

Jiang and Shanker point out that in the linear relationship between the actual speculative ratio and the hedging ratio, as in equation (7), both the intercept and slope have particular meanings. The intercept equals 1 plus the ratio of offsetting speculative contracts to short hedging and the slope equals the negative of the ratio of offsetting hedging contracts to long hedging, in a market in which short hedging equals or exceeds long hedging. There also need not be any systematic relationship between the intercept and the slope, as presumed by Working and described in equation (2). Comparing equations (2) and (7), if the intercepts are equal, so that $\alpha = \frac{SO}{HS}$, Working's conclusion that the slope equals $-(1-\alpha)$ implies that $\frac{SO}{HS} + \frac{HO}{HL} = 1$. This will not hold in a futures market, in general.

2.2.2 Situation in which long hedging exceeds short hedging

Suppose that $HL \geq HS$, *HO* represents offsetting hedging contracts and $M = HO/HS$ is the proportion of offsetting hedging contracts *HO* to short hedging contracts *HS,* then the required relationship between the speculative ratio and the hedging ratio, when short speculation is equal to the amount required to satisfy net long hedging demand, is given by:

$$\frac{SS_R}{HL} = 1 - M\frac{HS}{HL} \tag{9}$$

where SS_R is the required amount of short speculation. The actual relationship between the speculative ratio and the hedging ratio is given by:

$$\frac{SS_A}{HL} = 1 + \frac{SO}{HL} - M\frac{HS}{HL} \tag{10}$$

where SS_A is the actual amount of short speculation. Jiang and Shanker's measure of excessive speculation is then given by:

$$MES = 1 + \frac{SO}{HL} = \frac{SS_A}{HL} + M.\frac{HS}{HL} \qquad if\ HL \geq HS \tag{11}$$

2.3 Our indices of adequate and excessive speculation

We build upon the analysis of Jiang and Shanker to obtain our indices of adequate and excessive speculation.

2.3.1 Index of adequate speculation

Suppose that *HS≥HL*. We define adequate speculation as the amount of long speculation that is just sufficient to offset short hedging contracts which are in excess of offsetting hedging contracts. Equation (4) provides the required speculative ratio in this case, and this is also our index of adequate speculation. Thus, we define our index of adequate speculation *INDADSP* as:

$$INDADSP = 1 - M.\frac{HL}{HS} \qquad if\ HS \geq HL \tag{12}$$

Figure 1 graphs the required relationship between the speculative ratio and the hedging ratio of equation (4), when speculation is just sufficient to meet net hedging demand, for three different values of *M*. Line AB represents the situation in which *M*=0, and none of the long hedging contracts offset short hedging, line AC represents the situation in which *M*=0.5 and 50% of the long hedging contracts offset short hedging, while line AD represents the situation in which *M*=1 and 100% of the long hedging contracts offset short hedging. Consider a futures market which is characterized by *M*=0.5, so that 50% of the long hedging contracts offset short hedging contracts. Line A'C', which is parallel to line AC, represents the actual relationship between the speculative ratio and the hedging ratio for this market. Comparing equations (4) and (7), we note that the vertical distance between line AC and A'C' is always SO/HS. Point E, with actual values of the hedging ratio of 0.6 and speculative ratio of 0.9, represents the characteristics of this market at the same time. Then the index of adequate speculation *INDADSP* is the speculative ratio corresponding to point F, which lies on line AC and has the same hedging ratio as point E. We note that this equals (1-0.5x0.6) = 0.7.

Conducting a similar analysis for the situation in which *HL≥HS,* we note that in this case, the index of adequate speculation is given by:

$$INDADSP = 1 - M.\frac{HS}{HL} \qquad if \;\; HL \geq HS \tag{13}$$

The analysis of Figure 1 and the graphical representation of our index of adequate speculation also hold with the appropriate substitutions for the speculative ratio and the hedging ratio.

2.3.2 Index of excessive speculation

Suppose that *HS≥HL.* Comparing equations (6) and (4), and noting that the first term on the right hand side of equation (6) provides an estimate of the degree of adequate speculation, we define the index of excessive speculation *INDEXSP* as:

$$INDEXSP = \frac{SO}{HS} \qquad if \;\; HS \geq HL \tag{14}$$

Comparing equation (14) with equation (6), we note that:

$$INDEXSP = \frac{SL_A}{HS} + M.\frac{HL}{HS} - 1 \qquad if \;\; HS \geq HL \tag{15}$$

This can be seen to equal Jiang and Shanker's measure of excessive speculation minus 1. Further, comparing equation (14) with equation (7), we note that *INDEXSP* equals the intercept of the actual linear relationship between the speculative ratio and hedging ratio minus 1.

Consider Figure 1 and line AC, which represents the required relationship between the speculative ratio and the hedging ratio for a market in which 50% of the long hedging contracts offset short hedging contracts, and point E, with coordinates (0.6, 0.9), which represents the actual characteristics of the market at the same time, and lies on line A'C', which represents the actual relationship between the speculative ratio and hedging ratio for this market. Note that point F, which lies on line AC, shares the same hedge ratio of 0.6 as point E. Then the index of excessive speculation *INDEXSP* is given by the vertical distance between point E and point F, which equals (0.9-0.7) = 0.2. The index of excessive speculation *INDEXSP* also equals the intercept of line A'C' minus 1, which equals 0.2. In this situation, speculation is 20% in excess of that required to meet net hedging demand.

Conducting a similar analysis for the situation in which $HL \geq HS$, we note that in this case as well, the index of excessive speculation is given by:

$$INDEXSP = \frac{SO}{HL} \qquad if \ \ HL \geq HS \tag{16}$$

and:

$$INDEXSP = \frac{SS_A}{HL} + M.\frac{HS}{HL} - 1 \qquad if \ \ HL \geq HS \tag{17}$$

In addition, comparing equations (16) and (10), we note that *INDEXSP* equals the intercept of the actual linear relationship between the speculative ratio and hedging ratio minus 1. The analysis of Figure 1 and the graphical representation of our index of excessive speculation also hold with the appropriate substitutions for the speculative ratio and the hedging ratio.

2.4 Other measures of speculation

In our empirical analysis, we use Working's speculative index for comparison purposes. Working's speculative index is intended to measure speculation in excess of net hedging demand, although, as we point out, following Jiang and Shanker, he does this incorrectly.

Hence, its intent is similar to that of our index of excessive speculation *INDEXSP*. We also use two other measures of speculation. The first is De Roon et al's (2000) hedging pressure variable, which is the ratio of net short hedging (short hedging minus long hedging) to total hedging (sum of short and long hedging). This variable is a measure of net hedging demand and hence its intent is similar to that of our index of adequate speculation *INDADSP*. Note that the assumption implicit in this measure is that all long (short) hedging offsets short (long) hedging, if short (long) hedging equals or exceeds long (short) hedging. Since we are interested in analyzing the relationship between speculation and the crude oil futures price volatility, we use the absolute value of the hedging pressure variable in our analysis. Hence, our modification of De Roon et al's hedging pressure variable is *ADHEPR*, which is given by:

$$ADHEPR = \left| \frac{HS - HL}{HS + HL} \right| \tag{18}$$

The second measure is Sanders et al's (2004) speculative pressure variable, which is the ratio of net long speculation (long speculation – short speculation) to total speculation (long speculation plus short speculation). This variable is a measure of net speculation and hence should be a measure of net hedging demand. Therefore, its intent is similar to that of our index of adequate speculation *INDADSP*. Note that the assumption implicit in this variable is that all long (short) speculation offsets short (long) speculation, if short (long) speculation equals or exceeds long (short) speculation. Again, since we are interested in the relationship between speculation and the crude oil futures price volatility, we modify this variable to obtain the modified Sanders et al's speculative pressure variable *ASSPPR*, as follows:

$$ASSPPR = \left| \frac{SL - SS}{SL + SS} \right| \tag{19}$$

3. Data

3.1 Commitment of Traders (COT) data for crude oil futures

The CFTC provides a breakdown of the open interest for the crude oil futures market for each week in its Commitment of Traders (COT) report. These data are available for reporting traders (whose position exceeds a certain specified level) and for nonreporting traders. The reporting traders' positions are further classified into commercial (hedgers) and noncommercial (speculators). Commercial positions are classified into long and short positions, while noncommercial positions are classified into long, short and spread positions. The nonreporting traders' positions are classified into long and short positions. The as-of-date of the COT data is every Tuesday, and the release date is every Friday. We obtain the data for crude oil futures from the CFTC's website, which results in 729 weekly observations with as-of-dates extending from March 21, 1995 to March 10, 2009.

We first allocate the nonreporting traders' positions into hedging and speculative positions by assuming that the ratio of hedged to speculative positions is the same as that for the reporting traders, which is consistent with previous research. Next, we calculate the total long (short) open positions of hedgers, *HL* (*HS*), by summing up the long (short) positions of commercials and allocated nonreporting long (short) hedging positions. The total long (short) positions of speculators *SL* (*SS*) is calculated by summing up the noncommercial long (short), noncommercial spreads and allocated nonreporting long (short) speculative positions.

3.2 Crude oil futures price data

We use daily crude oil futures prices from the Energy Information Administration (EIA) website. Using 6,514 daily observations for the period April 4, 1983 through March 24, 2009, we extract a weekly data series as follows. First, we identify Tuesday observations. If a Tuesday observation does not exist for a specific week, we use the Monday just before that Tuesday. If a Monday observation does not exist either, we use the Wednesday, and then the Thursday and Friday, in that order. This process leads to 1,355 weekly observations, which include 1,340 Tuesday observations, 6 Monday observations and 9 Wednesday observations. We use these 1,355 observations to estimate the weekly conditional variance of futures prices.

3.3 Crude oil spot price data

We obtain daily spot prices of crude oil from the EIA website. Using 5,860 daily observations from January 2, 1986 to March 24, 2009, we extract weekly data by the same method as described above for the futures prices. We obtain 1,212 weekly observations, which include 1,201 Tuesday observations, 7 Monday observations, 3 Wednesday observations and 1 Thursday observation. We use these 1,212 observations to estimate the weekly conditional variance of spot prices.

3.4 Variables used to proxy fundamental factors

In order to find the net explanatory power of speculation upon the futures price volatility, we need to account for the effect of fundamental factors such as supply and demand, which are likely to influence this volatility. The domestic production, the inventory (stock) and the net import of crude oil could be factors that proxy supply, while the input of crude oil to refineries could be a proxy for demand.

We use the following control variables.

Proxy for domestic production *PROD*: Weekly U.S. Crude Oil Field Production (Thousand Barrels per Day).

Proxies for inventory: Weekly U.S. Crude Oil Ending Stocks Excluding the Strategic Petroleum Reserve (Thousand Barrels) *STEXCSPR* and Weekly U.S. Crude Oil Ending Stocks of the

Strategic Petroleum Reserve (Thousand Barrels) *STSPR*.

Proxy for net imports: Weekly U.S. Total Crude Oil and Petroleum Products Net Imports (Thousand Barrels per Day) *NETIMP*.

Proxy for demand: Weekly U.S. Crude Oil Inputs into Refineries (Thousand Barrels per Day) *INPREF*.

After downloading the data for these control variables from the EIA website, we obtain 1,383 weekly observations for the period August 20, 1982 to March 20, 2009. However, we only need 729 weekly observations for the same time period as for the COT data. The default as of date is Friday. Since we could not obtain daily data for these variables, we use the data for Friday to generate the weekly data series.

Some other variables such as cuts to output by the OPEC have been recognized by previous researchers as possible influential factors. We do not include these variables for two reasons. First, weekly data for these variables are unavailable. Some variables are available on a monthly basis while others are available on an annual basis. Second, these variables are more likely to influence the long-term equilibrium rather than short-term price dynamics in the crude oil futures market.

4. Methodology and results

The common period for all the data series used in the analysis is 21 March 1995 through 10 March 2009.

4.1 Estimation of measures of speculation

The measures of speculation are estimated by using the COT data obtained from the CFTC, and the resulting values for *HS*, *HL*, *SS* and *SL*.

4.1.1 Estimation of our indices of adequate speculation and excessive speculation

From the COT data available from the CFTC, we calculate a time series of weekly values of the actual speculative ratio, SPR_t, which equals $\frac{SL}{HS}$ if $HS \geq HL$ and $\frac{SS}{HL}$ otherwise, and of the hedging ratio HR_t, which equals $\frac{HL}{HS}$ if $HL \geq HS$ and $\frac{HS}{HL}$ otherwise, for each week t in the overall period. In order to estimate our index of adequate speculation *INDADSP* using equations (12) and (13), we need an estimate of M, which equals $\frac{HO}{HL}$ if $HS \geq HL$ and $\frac{HO}{HS}$ otherwise, where HO represents offsetting hedging contracts, for each week t. In order to estimate our index of excess speculation *INDEXSP* using equations (14) and (16), we need an estimate of $\frac{SO}{HS}$ if $HS \geq HL$ and $\frac{SO}{HL}$ otherwise, where SO represents offsetting speculative contracts, again for each week t. However, there are no data available from the CFTC or from any other source on the number of offsetting hedging contracts HO or offsetting speculative contracts SO. Note that M, which is needed to calculate *INDADSP*, equals the negative of the slope of the line which relates the actual speculative ratio to the hedging ratio, while *INDEXSP* has a value equal to the intercept of the same line minus 1. We expect both M and *INDEXSP,* which depend on offsetting hedging contracts and offsetting speculative contracts, respectively, to vary from week to week.

The actual relationship between the speculative ratio and the hedging ratio, which are provided in equation (7) in sub-section 2.2.1 for $HS \geq HL$ and equation (10) in sub-section 2.2.2 for $HL \geq HS$ may then be estimated by the following time-varying regression:

$$SPR_t = a_{0,t} + a_{1,t} HR_t + \varepsilon_t \tag{20}$$

where $a_{0,t}$ is the time-varying intercept, $a_{1,t}$ is the time-varying slope and ε_t is the error term. There are constraints on both the slope and the intercept as an examination of equations (7) and

(10) indicate. These are: $a_{0,t} \geq 1$, and $0 \geq a_{1,t} \geq -1$. We estimate the above time varying regression using a Kalman (1960) filter approach with inequality constraints on the state variables, following an approach suggested by Gupta and Hauser (2007). In equation (20), which represents the observation equation of the state-space representation, the speculative ratio SPR_t is the dependent observable variable, the hedging ratio HR_t is the exogenous observable variable, while $a_{0,t}$ and $a_{1,t}$ are state variables which represent the true state of the underlying system at time t. In the state-space representation, a state equation describes how the system transitions from the state at time $t-1$ to the state at time t.

As Welch and Bishop (2006) note, the unconstrained Kalman filter estimates the state variables through a recursive process, under which the state equation is used to provide an *a priori* prediction of the state at step t, given all information at step $t-1$. These estimates are then combined with the information provided by the observation on the dependent variable to provide an *a posteriori* estimate of the state variables. The objective is to minimize the mean square state estimate error. In order to address inequality constraints, Gupta and Hauser offer two approaches, one of which restricts the state estimate to lie in the constrained space by choosing an active set or "subset of the constraints" to treat as equality constraints. We use this approach in our estimation and describe it in what follows. We initially solve the unconstrained Kalman filter to estimate the state variables, using the software package Regression Analysis of Time Series (RATS) and the procedure DLM, which applies Kalman filtering to dynamic linear models. We then check whether the estimates of the state variables satisfy the inequality constraints. If any state variable estimates do not, we constrain the worst offender to lie on the boundary given by the inequality constraint. We re-estimate the Kalman filter with the constraint added. We continue this process until all state variable estimates meet the inequality constraints. The active set of constraints were for estimates of $a_{0,t}$ corresponding to the weeks ending May 16, 1995, May 23, 1995, December 14, 1999 and May 1, 2001.

Table 1 provides descriptive statistics for $a_{0,t}$, $a_{1,t}$, $INDADSP_t$ (estimated as $1+ a_{1,t}HR_t$ in accordance with equations (12) and (13)) and $INDEXSP_t$ (estimated as $a_{0,t} - 1$ in accordance with equations (14) and (16) and Figure 1) for each year in the period 1995 through 2009. The results on the minimum values of $a_{0,t}$ show that in 1995, 1999 and 2001, the minimum value was at the boundary of 1.00. The average value of $a_{0,t}$ ranges from a low of 1.0064 in 1995 to a high of 1.2550 in 2007. The results on the minimum values of $INDEXSP_t$ show that in 1995, 1999 and 2001, the minimum value was 0. The average value of the index of excessive speculation $INDEXSP_t$ ranges from 0.64% in 1995 to a high of 25.50% in 2008. From the table, we note that on average, speculation in excess of net hedging demand was in the range 0-5%, 5-10%, 10-15%, 15%-20% and greater than 25% for the years 1995-2001, 2002-2004, 2005-2006, 2007, and 2008-2009, respectively. Figure 2 shows the weekly estimates of $a_{0,t}$ along with the line which shows the boundary of the constraint that $a_{0,t} \geq 1$. The figure reinforces the conclusions on the increases in excessive speculation over the years from Table 1.

From Table 1, we note that the estimated values of $a_{1,t}$, which measures the slope of the linear relationship between the actual speculative ratio and the hedging ratio, are all well above the minimum value of -1 and increase over the years, ranging from a low of -0.8788 on average in 1995 to a high of -0.4570 on average in 2008. Thus M, which measures the proportion of offsetting hedging contracts to the lower hedging demand (short or long) equals - $a_{1,t}$, and has steadily decreased over the years. This indicates that the amount of speculation needed to satisfy net hedging demand has increased over time and this is borne out by the results on our index of adequate speculation $INDADSP_t$. We see that, on average, this ranges from a low of 17.24% in

1996 to a high of 56.42% in 2007. From the table, we note that on average, speculation that is required to meet net hedging demand was in the range 15-25%, 25-35%, 35-45%, 45%-55% and greater than 55% for the years 1995-2001, 2002-2004, 2005-2006, 2007, and 2008-2009, respectively. Figure 3 shows the weekly estimates of $a_{1,t}$ along with the line which shows the boundary of the constraint that $a_{1,t} \geq -1$. The figure reinforces the conclusions on the increases in the speculation required to meet net hedging demand over the years from Table 1.

4.1.2 Comparison of the results on our indices with the other measures of speculation

We estimate Working's *T* index *WOT* with equation (1), the modified De Roon et. al.'s measure of hedging pressure *ADHEPR* with equation (18) and the modified Sanders et. al.'s measure of speculative pressure *ASSPPR* with equation (19) for each week in the overall period.. Panel A of Table 2 shows the mean, standard deviation, skewness and kurtosis of our indices of adequate and excessive speculation, Working's index, the modified De Roon et al's hedging pressure variable and the modified Sanders et al's speculative pressure variable. On average, the results for our index of adequate speculation indicate that the proportion of adequate (long or short) speculation or net (short or long) hedging demand constitutes 30.61% of the highest hedging demand (short or long). The results for our index of excessive speculation indicate that offsetting speculative contracts constitute 7.03% of the highest hedging demand (long or short). On the other hand, the results for Working's speculative index indicate that speculation in excess of net hedging demand is 16.13%. Note, however, that following Jiang and Shanker, we have pointed out the errors inherent in Working's derivation of his speculative index. On average, the modified De Roon et al's hedging pressure variable is 3.30%, while the modified Sanders et al's speculative pressure variable is 12.14%. Recall, however, that the De Roon et al's hedging pressure variable implicitly assumes that all long (short) hedging offsets short (long) hedging contracts or, in other words, that $M=1$, while the Sanders et al's speculative pressure variable implicitly assumes that all long (short) speculation offsets short (long) speculation. This explains why, on average, the modified De Roon et al's hedging pressure variable and the modified Sanders et al's speculative pressure variable are much less than our index of adequate speculation *INDADSP*, which is based on explicitly estimating M and accounting for offsetting hedging contracts.

4.2 Estimation of measures of volatility

A time series of the weekly return on the crude oil futures contract is created using:

$$r_t = \ln\left(\frac{F_t}{F_{t-1}}\right) \tag{21}$$

where F_t is the futures price in week t. The conditional variance of the futures return in week t, h_t, is then estimated by using the following GARCH (1, 1) model.

$$r_t = \mu + \varepsilon_t \tag{22}$$

$$h_t = w + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \tag{23}$$

where μ, w, α and β are the parameters and ε_t is the error term. The volatility of the crude oil futures price *VOFT* for each week t is set equal to h_t. This process is repeated using the spot price of crude oil to estimate the volatility of the spot price *VOST* for each week t. Table 3 shows the results of the estimation of the GARCH(1,1) model for crude oil futures and for crude oil. Note that all the available weekly data is used in the estimation. Panel B of Table 2 shows the mean, standard deviation, skewness and kurtosis of the estimates of conditional volatility for both crude oil futures and spot prices over the period 21 March 1995 through 10 March 2009. On average, the conditional volatility of both crude oil futures and crude oil spot prices are similar in magnitude.

4.3 Values of the control variables

Panel C of Table 2 shows the mean, standard deviation, skewness and kurtosis of the weekly values of the control variables *PROD*, *STEXCSPR*, *STSPR*, *NETIMP* and *INPREF*.

4.4 Relationship between the measures of speculation and futures price volatility

4.4.1 Relationship between speculation and futures price volatility in the overall period

In order to identify the explanatory power of the measures of speculation upon the futures price volatility, we conduct the following multiple regression analysis of the futures price volatility on the measure of speculation and the control variables, which include the spot price volatility, and the variables which proxy for the demand and supply of crude oil.

$$\begin{aligned} VOFT_t = {} & c_0 + c_1 * IND_t + c_2 * VOST_t + c_3 * PROD_t + c_4 * STEXCSPR_t + c_5 * STSPR_t + \\ & c_6 * NETIMP_t + c_7 * INPREF_t + \varepsilon_t \end{aligned} \tag{24}$$

where IND_t stands for the measure of speculation in week t. *IND* is in turn *INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ASSPPR*. The coefficient c_1 is an estimate of the relationship between the measure of speculation and the futures price volatility. The results are presented in Table 4. The results indicate that the adjusted R squared of each regression is high, ranging from a low of 80.55% with *INDADSP* as the measure of speculation to a high of 80.79%% with *ASSPPR* as the measure of speculation.

First, we examine the relationship between each measure of speculation and the futures price volatility. The results show that our index of adequate speculation *INDADSP* is not related to the futures price volatility. Our index of excessive speculation *INDEXSP* is significantly positively related to the futures price volatility, as is Working's speculative index *WOT*. In contrast, both *ADHEPR* and *ASSPPR* are significantly negatively related to the futures price volatility.

In each of the regressions, the futures price volatility is significantly positively related to the spot price volatility *VOST*, negatively related to the stock of crude oil in the strategic petroleum reserve, *STSPR*, and positively related to the input of oil to refineries, *INPREF*. These relationships correspond with what we would expect intuitively. The stock of oil in the U. S. excluding the strategic petroleum reserve *STEXCSPR*, the U. S. crude oil field production *PROD* and the net imports of crude oil *NETIMP* are not statistically significantly related to the futures price volatility in any of the regressions.

4.4.2 Breakdown of overall period into sub-periods

As we noted in the introduction section, in our sample period, there are four major policy events, which may have led to structural changes in the WTI crude oil futures market. We provide a brief description of these events. First, the CFMA was passed by Congress and signed into law by President Bill Clinton on December 21, 2000. This act permitted large professional traders to bypass the regulated exchanges and trade commodities on over-the-counter, electronic markets. This should have had the effect of decreasing speculative activity on the NYMEX crude oil futures contract, if speculators moved from this market to markets which were not subject to oversight by the CFTC. Our index of excessive speculation *INDEXSP* and Working's speculative index *WOT*, which are both intended to measure speculation in excess of net hedging demand, would be expected to decrease. The CFMA is often claimed to have created the so-called 'swaps loophole', which opened the door for swap dealers to help index traders to take huge speculative positions in commodity indexes through swaps. The swap dealers hedged the risk of their swaps positions in the futures markets. These futures positions were granted a 'bona fide hedging exemption' and were therefore treated as hedges by the CFTC and not subject to speculative position limits. This should have had the effect of increasing hedging activity on the

NYMEX. Our index of adequate speculation *INDADSP*, the modified De Roon et al's hedging pressure variable *ADHEPR*, and the modified Sanders et al's speculative pressure variable *ASSPPR*, which are all intended to measure net hedging demand, would be expected to increase.

Second, on November 13, 2002, the CFTC published the Advance Notice of Proposed Rulemaking on Commodity Pool Operator (CPO) and Commodity Trading Advisor (CTA) Registration Exemptions. This proposed exemptions from registration as a CPO by operators of hedge funds and exemptions from registration as a CTA by advisers to hedge funds, when certain criteria are met, as well as temporary immediately available no-action relief while the proposed exemptions were under review. John Damguard, then President of the Futures Industry Association notes in his letter (Damguard (2003)) to the CFTC of January 17, 2003, that these exemptions "should encourage the participation of collective investment vehicles" in exchange-traded futures markets. This policy change, therefore, should have had the effect of increasing speculative activity on the NYMEX, and therefore, *INDEXSP* and *WOT*.

Third, on March 11, 2003, the Federal Reserve (2003) proposed an amendment to Regulation Y, in answer to requests by Citicorp and the Union Bank of Switzerland. Under Regulation Y, a bank holding company could only enter into a commodity contract if the commodity is eligible for investment by a state member bank, the contract is cash-settled or the contract can be assigned, terminated or offset prior to delivery. The amendment would permit bank holding companies: 1) to enter into commodity contracts that would allow them to receive and instantaneously transfer title to the assets underlying the contracts, and; 2) to enter into commodity contracts that do not allow for assignment, termination or offset prior to delivery, if the contract is based on an asset for which futures contracts or options on futures have been approved for trading on an exchange regulated by the CFTC. The final rule became effective on

August 4, 2003. This modification to Regulation Y allowed many banks to engage in a wider array of commodity derivative activities. This should have had the effect of increasing both speculative activity and hedging activity on the NYMEX, and therefore, all the measures of speculation, *INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ASSPPR*.

Fourth, on February 3, 2006, ICE Futures Europe, a London-based subsidiary of ICE, began trading the WTI crude oil futures. Thus, it was claimed by some critics, that ICE's electronic trading platform provided traders a way to circumvent the regulatory oversight of CFTC. This could have had the effect of decreasing speculative activity if traders moved from the NYMEX to the ICE. On the other hand, it could have increased speculative activity, since arbitragers could have initiated arbitrage trades between the NYMEX and ICE crude oil futures contracts. Thus, both *INDEXSP* and *WOT* could be expected to increase or decrease.

As mentioned in Section 1, this allows us to divide the overall period into five sub-periods, whose details are presented in Table 5. The sub-periods correspond to: 1) the benchmark sub-period preceding all policy changes; 2) the sub-period following granting of exemption to the ICE from CFTC oversight and exemption to banks from speculative position limits; 3) the sub-period following relaxation of rules to hedge funds; 4) the sub-period following the granting of permission to banks to engage in expanded commodity derivatives activity and 5) the sub-period following initiation of trading of a WTI crude oil futures contract on the ICE. The last two columns of Table 5 provide the hypothesized effect upon activity in the NYMEX crude oil futures contract and upon the measures of speculation, respectively, in sub-periods 2 through 5. Summing up, if the policy changes have the hypothesized effects, net hedging demand is expected to increase in sub-periods 2 and 4, while speculation in excess of net hedging demand is expected to decrease in sub-period 2, increase in sub-periods 3 and 4, and increase or decrease in sub-period 5.

Variation in the measures of speculation in the different sub-periods is investigated by conducting a regression analysis of the following equation.

$$DEP_t = b_0 + b_1 * D_1 + b_2 * D_2 + b_3 * D_3 + b_4 * D_4 + \varepsilon_t \tag{25}$$

Where *DEP* is in turn *INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ASSPPR*, and D_1, D_2, D_3, and D_4 are dummy variables with values=1 for sub-periods 2, 3, 4 and 5, respectively and 0 otherwise, and ε_t is the error term. Table 6 shows the results of the analysis. The results indicate that the measure of adequate speculation *INDADSP* is 20.04% on average in sub-period 1 and that it increases significantly relative to sub-period 1 in each of the remaining sub-periods. These results are consistent with the hypothesized effects of an increase in the net hedging demand in sub-periods 2 and 4, and are indicative of a strong effect of the policy changes upon net hedging demand. The measure of excessive speculation *INDEXSP* is 1.49% on average in sub-period 1 and it increases significantly relative to sub-period 1 in each of the remaining sub-periods. The result for this variable in sub-period 2 is contrary to the hypothesized effect of a decrease in speculation in excess of net hedging demand. The results for Working's speculative index *WOT* indicates that excessive speculation is 7.78% on average in sub-period 1 and it increases significantly in the remaining sub-periods. The result for this variable in sub-period 2 are also contrary to the hypothesized effect of a decrease in speculation in excess of net hedging demand. The results for the modified De Roon et al's hedging pressure variable *ADHEPR* indicates that hedging pressure is 3.40% on average in sub-period 1, increases significantly in sub-period 2 and decreases significantly in sub-period 5. The results for this variable are contrary to the hypothesized effect of no change in the net hedging demand in sub-period 5. The results for the modified Sanders et al.'s speculative pressure variable *ASSPPR* indicates that speculative pressure is 17.27% on average in sub-period 1, and it decreases significantly in sub-periods 3, 4 and 5, relative to sub-period 1. These results are contrary to the hypothesized effects of increases in net hedging demand in sub-periods 2 and 4 and no effects in sub-periods 3 and 5.

4.4.3 Analysis of the relationship between the crude oil futures price volatility and speculation in the different sub-periods

In order to identify the explanatory power of the measures of speculation upon the futures price volatility in the different sub-periods, we conduct the following multiple regression analysis of the futures price volatility on the measure of speculation and the control variables, which include the spot price volatility, and the variables which proxy for the demand and supply of crude oil.

$$\begin{aligned} VOFT_t = {} & c_0 + c_1 * IND_t + c_2 * D_1 * IND_t + c_3 * D_2 * IND_t + c_4 * D_3 * IND_t + \\ & c_5 * D_4 * IND_t + c_6 * VOST_t + c_7 * PROD_t + c_8 * STEXCSPR_t + c_9 * STSPR_t + \\ & c_{10} * NETIMP_t + c_{11} * INPREF_t + \varepsilon_t \end{aligned} \quad (26)$$

where IND_t stands for the measure of speculation in week *t*. *IND* is in turn *INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ASSPPR*. The coefficient c_1 is an estimate of the relationship between the measure of speculation and the futures price volatility in sub-period 1. D_1, D_2, D_3 and D_4 are dummy variables which assume a value = 1 if the weekly observation is from sub-period 2, 3, 4 and 5, respectively, and equal 0 otherwise. The coefficients c_2, c_3, c_4 and c_5 therefore estimate whether the relationship between the measure of speculation and the crude oil futures volatility in sub-periods 2, 3, 4 and 5, respectively, differs significantly from the relationship in sub-period 1. The results are presented in Table 7. The results indicate that the adjusted R squared of each regression is high, ranging from a low of 80.92% with *INDADSP* as the measure of speculation to a high of 82.07% with *ASSPPR* as the measure of speculation.

First, we examine the relationship between each measure of speculation and the futures price volatility. The results show that our index of adequate speculation *INDADSP* is negatively but not statistically significantly related to the futures price volatility in sub-period 1. In sub-period 3, this relationship differs significantly from that in sub-period 1, in that it becomes less negative. Our index of excessive speculation *INDEXSP* is significantly positively related to the futures price volatility in sub-period 1, as indicated by the *t* statistic of 3.0597. Thus in sub-period 1, the effect of excessive speculation is to increase the volatility of the futures price. The coefficients c_2, and c_5 are significantly negative, indicating that the relationship between speculation and volatility is significantly less positive in sub-periods 2, and 5, than the relationship in sub-period 1. Working's speculative index *WOT* is significantly positively related to the futures price volatility in sub-period 1 and this relationship is significantly less positive in sub-period 2. Both *ADHEPR* and *ASSPPR* are significantly negatively related to the futures price volatility in sub-period 1. For *ADHEPR*, the relationship is significantly less negative in sub-periods 2, and 4, and positive in sub-period 3. For *ASSPPR*, the relationship is positive in sub-period 3 and negative in sub-period 5.

In each of the regressions, the futures price volatility is significantly positively related to the spot price volatility *VOST*, negatively related to the stock of crude oil in the strategic petroleum reserve, *STSPR*, and positively related to the input of oil to refineries, *INPREF*. These relationships correspond with what we would expect intuitively. The stock of oil in the U. S. excluding the strategic petroleum reserve *STEXCSPR* is unrelated to the futures price volatility in the first three regressions in which the measures of speculation are our index of adequate speculation, our index of excessive speculation and Working's index, and significantly positively related to the futures price volatility in the last two regressions in which the measure of speculation is the modified De Roon et al's hedging pressure variable and the modified Sanders et al's speculative pressure variable. The U. S. crude oil field production *PROD* and the net imports of crude oil *NETIMP* are not statistically significantly related to the futures price volatility in any of the regressions.

4.4.4 Granger causality analysis of the relationship between the futures price volatility and the measures of speculation

We next test whether the crude oil futures price volatility is caused by each of the measures of speculation and whether each measure of speculation is caused by the crude oil futures volatility by conducting a Granger causality analysis.

The following two equations are analyzed:

$$VOFT_t = d_{10} + \sum_{i=1}^{L} d_{1i} VOFT_{t-i} + \sum_{i=1}^{L} e_{1i} Measure\ of\ \ speculation_{t-i} + \varepsilon_{1t} \tag{27}$$

$$Measure\ of\ \ speculation_t = d_{20} + \sum_{i=1}^{L} d_{2i} Measure\ of\ \ speculation_{t-i} + \sum_{i=1}^{L} e_{2i} VOFT_{t-i} + \varepsilon_{2t} \tag{28}$$

Equation (27) is used to test whether the measure of speculation Granger causes the volatility of the crude oil futures price, while equation (28) is used to check whether the volatility of the crude oil futures price Granger causes the measure of speculation. *L* represents the number of lags used in the analysis, d_{10}, d_{11} through d_{1L} and e_{11} through e_{1L} are the coefficients and ε_{1t} is the error term in equation (27), while d_{20}, d_{21} through d_{2L} and e_{21} through e_{2L} are the coefficients and ε_{2t} is the error term in equation (28). The above system of equations is analyzed using a vector autoregressive analysis (VAR). First the appropriate lag length is determined by running the VAR with *L*=10. The results for the Akaike information criterion, the Schwarz information criterion and the Hannan-Quinn information criterion indicate that the largest appropriate lag length is 3. Hence we use a lag length of 4 to conduct the VAR estimation. The results are presented in Table 8. The F statistics for null hypotheses 1 through 5 indicate that none of the measures of speculation Granger cause the futures price volatility. The F statistics for null hypotheses 6 through 10 indicate that the futures price volatility does not Granger cause the measures of speculation, with the exception of our index of excessive speculation INDEXSP and Working's speculative index WOT.

5. Conclusion

We offer innovative indices of adequate and excessive speculation in a futures market. We define adequate speculation as long (short) speculation that is just sufficient to meet net hedging demand, which is short (long) hedging in excess of offsetting long (short) hedging contracts, when short (long) hedging equals or exceeds long (short) hedging. Excessive speculation is long (short) speculation in excess of this amount and is essentially measured by the number of offsetting speculative contracts. Our indices explicitly take into account the effect of offsetting hedging contracts. While Working offers a speculative index which is widely used, and whose intent is to measure speculation in excess of net hedging demand, we point out, following Jiang and Shanker, that Working's index is based on an incorrect assumption of the true relationship between the speculative ratio and the hedging ratio that should prevail in a futures market. Our analysis and our indices correct this assumption.

We next estimate our indices for the West Texas Intermediate (WTI) crude oil futures contract traded on the New York Mercantile Exchange (NYMEX) over the period 1995 through 2009, using data on the open futures positions of commercial and noncommercial traders that is provided by the CFTC in its COT reports. In order to estimate our indices, we need data on the number of offsetting hedging contracts and offsetting speculative contracts, which is not available from the CFTC or any other source. We note that the relationship between the actual speculative ratio and the hedging ratio is linear, that the intercept of the line depends on offsetting speculative contracts and the slope of the line depends on offsetting hedging contracts. The dependent variable in the regression is the speculative ratio and the independent variable is the hedging ratio. Since the number of offsetting speculative and hedging contracts could vary from week to week, the intercept and slope of the line are both time varying. In addition, the characteristics of the actual linear relationship dictate that the intercept must be constrained to be greater than or equal to 1, while the slope must be constrained to be less than or equal to 0 and greater than or equal to -1. Accordingly, we estimate the time varying intercept and slope of the regression by applying a state-space approach using Kalman filtering with inequality constraints on the state variables—the intercept and the slope. From these estimates we estimate our indices of adequate speculation and excessive speculation. Our results show that the proportion of offsetting hedging contracts decreased on average from a high of 87.88% in 1995 to a low of 45.70% in 2008. Correspondingly, our index of adequate speculation rose on average from a low of 17.24% in 1996 to a high of 56.42% in 2008. Our index of excessive speculation rose from a low of 0.64% in 1995 to a high of 25.50% in 2008.

For comparison purposes, we estimate three other measures of speculation, Working's *T* index, the absolute value of De Roon et al's hedging pressure variable and the absolute value of Sanders et al's speculative pressure variable. We use the absolute values of the hedging pressure and speculative pressure variables, since our objective is to determine the relationship between speculation and the volatility of the futures price, rather than the direction of the futures price move, if any. We have already pointed out the errors inherent in the derivation of Working's *T* index. De Roon et al's hedging pressure variable implicitly assumes that all long (short) hedging contracts offset short (long) hedging contracts. Sanders et al's speculative pressure variable implicitly assumes that all long (short) speculation offsets short (long) speculation. The intent behind Working's *T* index is to measure speculation in excess of net hedging demand and hence, it is similar to that of our index of excessive speculation. However, on average, excessive speculation as measured by Working's *T* index is much higher than our index of excessive speculation. We conclude that the errors in Working's assumption causes his index to overestimate the degree of excessive speculation. The intent behind De Roon et al's hedging pressure variable and Sanders et al's speculative pressure variable is to measure net hedging demand, and hence the intent behind these indices is similar to that of our index of adequate speculation. On average, the modified De Roon et al's hedging pressure variable and the modified Sanders et al's speculative pressure variable are much lower than our index of adequate speculation. Recall that both our index of adequate speculation and excessive speculation are based on an explicit modeling and estimation of offsetting hedging contracts. We conclude that the implicit assumptions of the De Roon et al's hedging pressure variable and the Sanders et al's speculative pressure variable, causes these measures to underestimate net hedging demand.

In the overall period, we find that our index of adequate speculation or net hedging demand is unrelated to the futures price volatility. However, our index of excessive speculation or speculation in excess of net hedging demand is significantly positively related to the futures price volatility. These results are echoed by use of Working's speculative index. However, both the modified De Roon et al's hedging pressure variable and the modified Sanders et al's speculative pressure variable are significantly negatively related to the futures price volatility in the overall period.

We investigate the impact of regulatory policy changes. These include: the CFMA of 2000, which effectively granted exemption from CFTC oversight to the ICE and exemption from speculative position limits to swap dealers, the relaxation of the rules governing futures trading by hedge funds, the relaxation of the rules governing futures trading by banks, and the introduction of a WTI crude oil futures contract on the ICE. We break down the overall period into a benchmark period which precedes all policy changes and four other sub-periods which follow each policy change. On average, our index of adequate speculation or net hedging demand is 20.04% in the benchmark period and increases significantly in each following sub-period relative to the benchmark period, reaching its maximum of 49.26% in sub-period 5, which extends from February 3, 2006 till March 10, 2009. This is consistent with the effect of the 'swaps loophole' under which participation by swap dealers in the futures markets was facilitated following the CFMA of 2000. As remarked earlier, these futures positions were granted the 'bona fide hedging exemption' and therefore treated as hedging positions rather than speculative positions. Stupak (2009) further notes that since 2006, 'the NYMEX granted 117 bona fide hedging exemptions' for the WTI crude oil futures contract. Our index of excessive speculation is 1.49% on average in the benchmark period and increases significantly from this value in each of the following sub-periods, reaching its maximum of 19% on average in sub-period 5. Working's *T* index, which is also supposed to measure speculation in excess of net hedging demand, increases significantly in each sub-period, relative to the benchmark period. The modified De Roon et al's hedging pressure variable and the modified Sanders et al's speculative pressure variable, which are supposed to measure net hedging demand, both decrease significantly in sub-period 5 relative to the benchmark period. This is contrary to our expectation that hedging activity should increase in sub-period 5 in accordance with Stupak's observation.

Our empirical results indicate, that our index of adequate speculation, or speculation that is just sufficient to meet net hedging demand, is unrelated to the futures price volatility in sub-period 1, and there is no difference between this result and those of sub-periods 2, 4 and 5. This is contrary to the results of De Roon et al, who find that futures returns are related to the degree of hedging pressure, but consistent with the results of Gorton et al (2008), who find no evidence that hedging pressure affects futures risk premiums. This result provides support to those who would argue that the trades of swap dealers do not destabilize the futures market and that the 'bona fide hedging exemption' should not be denied to swap dealers.

Prior to the passage of the CFMA, our index of excessive speculation is significantly positively related to the futures price volatility. This result is consistent with the presence of 'noise' traders in the futures market, whose effect is to reduce the stability provided by the arbitrageurs. However, in the sub-periods following the granting of exemption to the ICE from CFTC oversight and granting of permission for the ICE to trade the WTI crude oil futures contract, this positive relationship is significantly reduced in magnitude. This is consistent with the presence of rational arbitrageurs in the market, as explained by Freidman. It is also consistent with the position of those who would argue that a certain degree of speculation in excess of net hedging demand is necessary to add liquidity to and stabilize the market.

Working's *T* index is positively related to the futures price volatility in the benchmark period. This relationship is significantly less positive in sub-period 2. In contrast to the results on the lack of a relationship between our index of adequate speculation and the futures price volatility, both the modified De Roon et al's hedging pressure variable and the modified Sanders et al's speculative pressure variable are significantly negatively related to the futures price volatility in the benchmark period. This relationship becomes positive in sub-period 3, which follows the relaxation of rules to hedge funds. We consider that these differences could arise due to the underestimation of the net hedging demand by the hedging pressure and speculative pressure variables.

With regard to the effect of fundamental factors, the results show that the futures price volatility is significantly negatively related to the stock of crude oil in the SPR, which proxies for supply and positively related to the input of oil to refineries, which proxies for demand. These results are in line with what would be expected on the basis of intuition.

The Granger causality analysis indicates none of the measures of speculation Granger cause the futures price volatility. The futures price volatility Granger causes our index of excessive speculation and Working's speculative index, but not the other measures of speculation. While it is tempting to conclude from this that increases in speculation do not lead to increases in volatility, we should point out that the Commitment of Traders reports provide information on traders' positions on a weekly basis. Hence, the indices of speculation and the futures price volatility are calculated on a weekly basis. It is very likely that using weekly data may have prevented any causality effects from being detected. The collection of higher frequency data on traders' positions is therefore desirable.

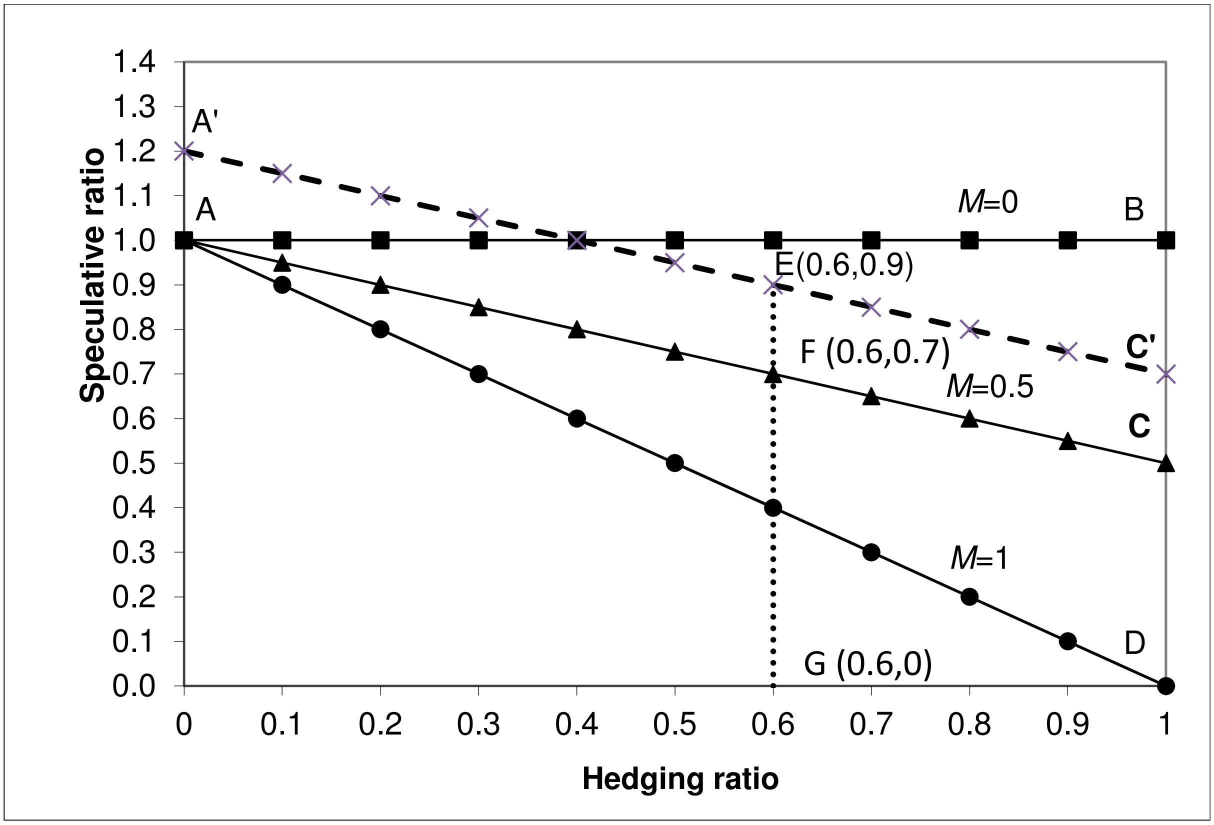

Figure 1. The required relationship between the speculative ratio and the hedging ratio for various values of *M* and of the index of adequate speculation *INDADSP* and excessive speculation *INDEXSP*

Lines AB, AC and AD represent the required relationship between the speculative ratio and the hedging ratio, when speculation is just sufficient to meet net hedging demand, for values of *M*=0, *M*=0.5 and *M*=1 respectively. Line A'C' represents the actual relationship between the speculative ratio and the hedging ratio for *M*=0.5

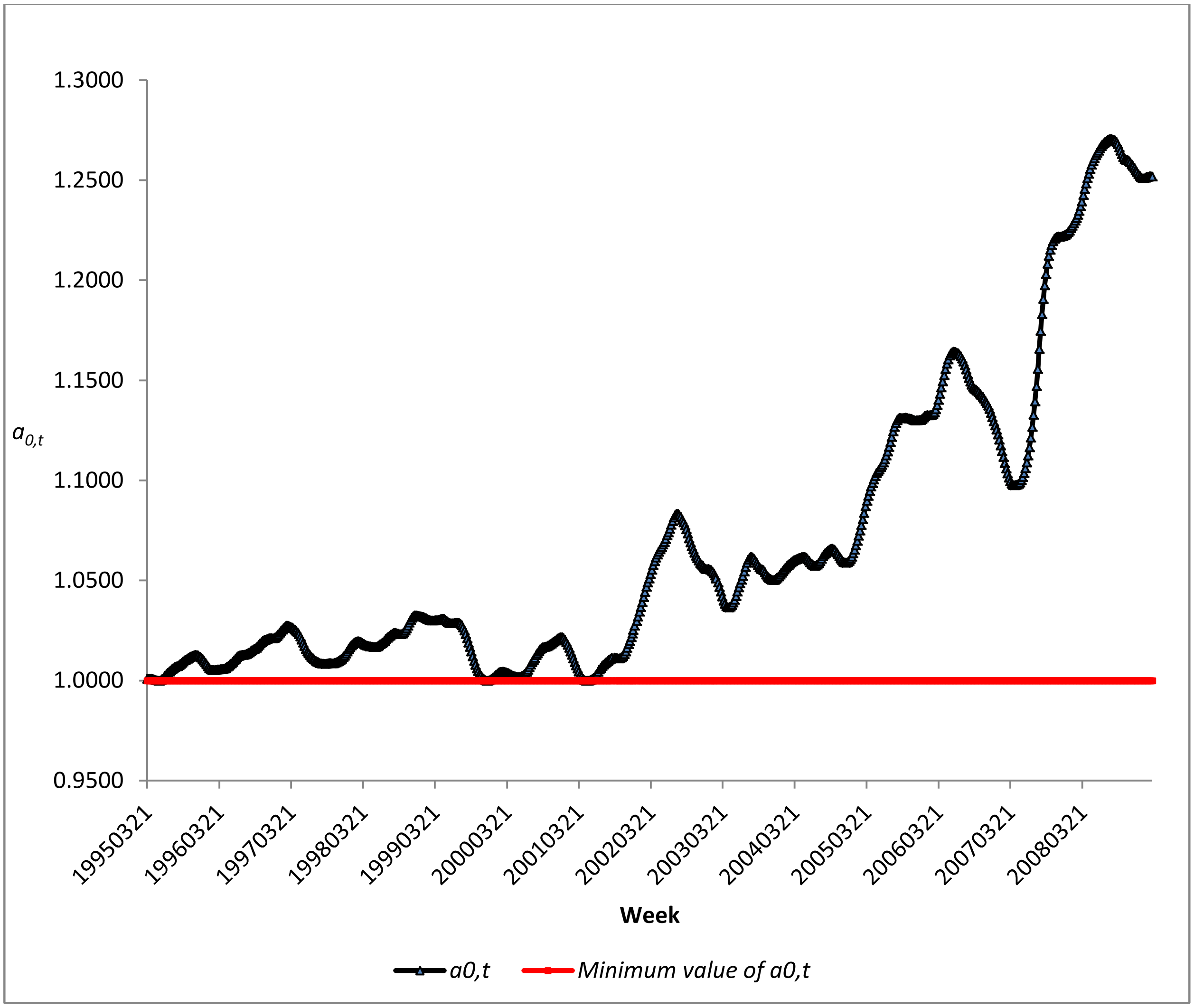

Figure 2 Weekly estimates of $a_{0,t}$ are shown in the figure along with the line which shows the boundary of the constraint that $a_{0,t} \geq 1$

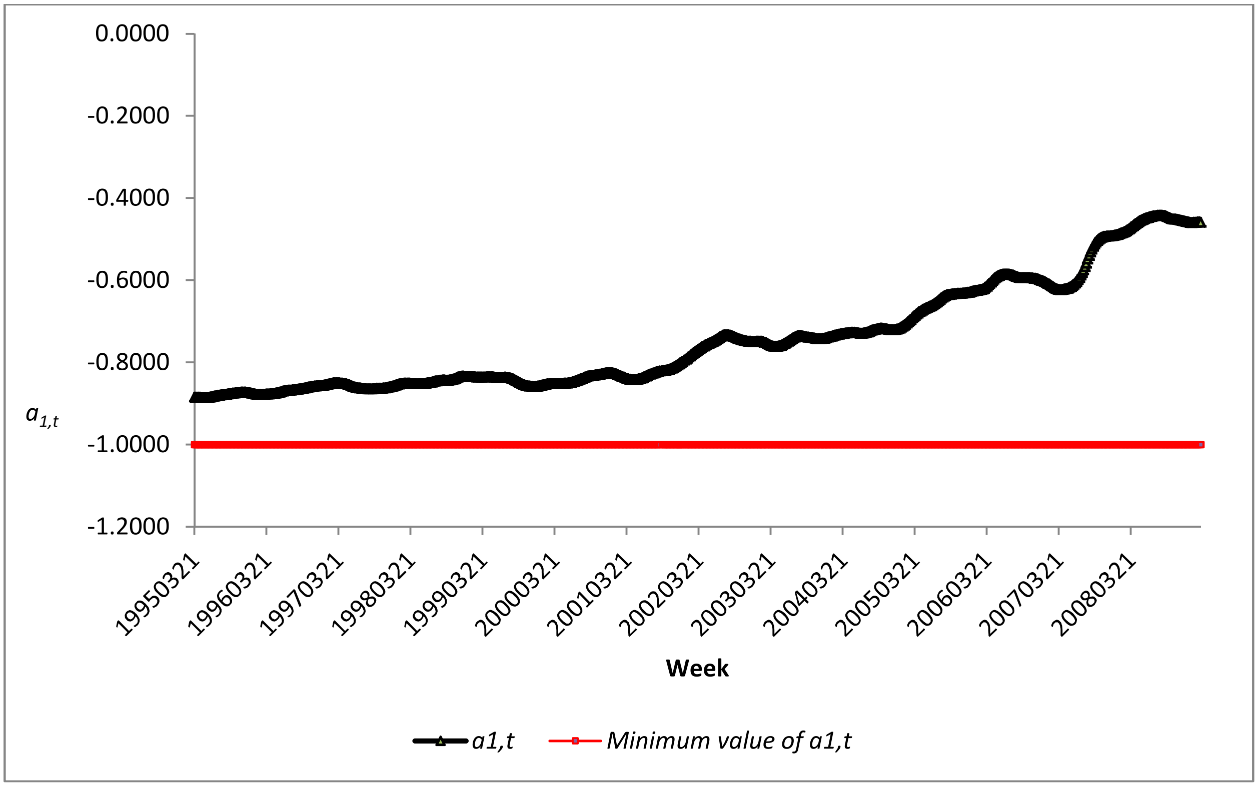

Figure 3 Weekly estimates of $a_{1,t}$ are shown in the figure along with the line which shows the boundary of the constraint that $a_{1,t} \geq -1$

Table 1 Summary statistics of state variables $a_{0,t}$ and $a_{1,t}$, the index of adequate speculation *INDADSP* and the index of excessive speculation *INDEXSP* over the period 21 March 1995 through 10 March 2009

Year	Number of Observations	Variable	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
1995	41	$a_{0,t}$	1.0000	1.0128	1.0064	0.0047	-0.0300	-1.6170
		$a_{1,t}$	-0.8855	-0.8721	-0.8788	0.0050	-0.0190	-1.6180
		$INDADSP_t$	0.1234	0.2901	0.2021	0.0519	0.2230	-1.2610
		$INDEXSP_t$	0.0000	0.0128	0.0064	0.0047	-0.0300	-1.6170
1996	53	$a_{0,t}$	1.0053	1.0218	1.0125	0.0057	0.2670	-1.3300
		$a_{1,t}$	-0.8778	-0.8557	-0.8681	0.0075	0.2360	-1.3830
		$INDADSP_t$	0.1278	0.2346	0.1724	0.0253	0.2410	-0.4550
		$INDEXSP_t$	0.0053	0.0218	0.0125	0.0057	0.2670	-1.3300
1997	52	$a_{0,t}$	1.0084	1.0275	1.0161	0.0073	0.4170	-1.5730
		$a_{1,t}$	-0.8640	-0.8491	-0.8577	0.0054	0.3500	-1.4860
		$INDADSP_t$	0.1394	0.3062	0.1975	0.0392	0.9860	0.2970
		$INDEXSP_t$	0.0084	0.0275	0.0161	0.0073	0.4170	-1.5730
1998	52	$a_{0,t}$	1.0157	1.0327	1.0220	0.0050	0.9500	-0.1840
		$a_{1,t}$	-0.8547	-0.8333	-0.8457	0.0062	0.7140	-0.6640
		$INDADSP_t$	0.1578	0.2893	0.1950	0.0306	1.5500	2.2380
		$INDEXSP_t$	0.0157	0.0327	0.0220	0.0050	0.9500	-0.1840
1999	52	$a_{0,t}$	1.0000	1.0322	1.0217	0.0118	-0.9270	-0.8770
		$a_{1,t}$	-0.8584	-0.8337	-0.8417	0.0092	-0.9180	-0.9270
		$INDADSP_t$	0.1683	0.3077	0.2396	0.0397	-0.0950	-1.2030
		$INDEXSP_t$	0.0000	0.0322	0.0217	0.0118	-0.9270	-0.8770
2000	52	$a_{0,t}$	1.0011	1.0217	1.0095	0.0073	0.4510	-1.5060
		$a_{1,t}$	-0.8564	-0.8241	-0.8417	0.0105	0.3560	-1.4870
		$INDADSP_t$	0.1503	0.2409	0.1961	0.0222	0.2540	-0.7360
		$INDEXSP_t$	0.0011	0.0217	0.0095	0.0073	0.4510	-1.5060
2001	52	$a_{0,t}$	1.0000	1.0275	1.0102	0.0073	0.3990	-0.5620
		$a_{1,t}$	-0.8419	-0.7969	-0.8260	0.0123	0.6100	-0.4120
		$INDADSP_t$	0.1593	0.3597	0.2437	0.0559	0.3850	-0.8540
		$INDEXSP_t$	0.0000	0.0275	0.0102	0.0073	0.3990	-0.5620
2002	52	$a_{0,t}$	1.0298	1.0834	1.0632	0.0143	-0.5470	-0.3340
		$a_{1,t}$	-0.7943	-0.7323	-0.7528	0.0173	-0.9220	-0.1210
		$INDADSP_t$	0.2305	0.3651	0.3037	0.0308	-0.2510	-0.2120
		$INDEXSP_t$	0.0298	0.0834	0.0632	0.0143	-0.5470	-0.3340

Table 1 continued

Year	Number of observations	Variable	Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis
2003	52	$a_{0,t}$	1.0366	1.0620	1.0506	0.0074	-0.4960	-0.7240
		$a_{1,t}$	-0.7610	-0.7345	-0.7461	0.0085	-0.4040	-1.1580
		$INDADSP_t$	0.2479	0.3741	0.3044	0.0319	0.0660	-0.7900
		$INDEXSP_t$	0.0366	0.0620	0.0506	0.0074	-0.4960	-0.7240
2004	52	$a_{0,t}$	1.0529	1.0660	1.0604	0.0030	-0.1020	-0.0270
		$a_{1,t}$	-0.7384	-0.7166	-0.7253	0.0061	-0.2260	-0.9190
		$INDADSP_t$	0.2815	0.3898	0.3287	0.0319	0.2400	-1.0120
		$INDEXSP_t$	0.0529	0.0660	0.0604	0.0030	-0.1020	-0.0270
2005	52	$a_{0,t}$	1.0620	1.1315	1.1092	0.0228	-0.6840	-0.8330
		$a_{1,t}$	-0.7159	-0.6281	-0.6599	0.0281	-0.5510	-1.0150
		$INDADSP_t$	0.2876	0.4347	0.3754	0.0354	-0.5480	-0.1100
		$INDEXSP_t$	0.0620	0.1315	0.1092	0.0228	-0.6840	-0.8330
2006	52	$a_{0,t}$	1.1295	1.1644	1.1466	0.0115	0.2150	-1.3560
		$a_{1,t}$	-0.6269	-0.5843	-0.5996	0.0138	-0.8840	-0.6570
		$INDADSP_t$	0.3759	0.4838	0.4272	0.0301	0.2150	-1.1130
		$INDEXSP_t$	0.1295	0.1644	0.1466	0.0115	0.2150	-1.3560
2007	53	$a_{0,t}$	1.0977	1.2233	1.1515	0.0504	0.4040	-1.6260
		$a_{1,t}$	-0.6227	-0.4898	-0.5662	0.0533	0.3890	-1.6540
		$INDADSP_t$	0.3863	0.5620	0.4629	0.0550	0.1960	-1.5400
		$INDEXSP$	0.0977	0.2233	0.1515	0.0504	0.4040	-1.6260
2008	52	$a_{0,t}$	1.2241	1.2707	1.2550	0.0145	-0.9000	-0.4580
		$a_{1,t}$	-0.4889	-0.4414	-0.4570	0.0147	-0.9470	-0.4030
		$INDADSP_t$	0.5281	0.5936	0.5642	0.0143	-0.5450	0.5550
		$INDEXSP_t$	0.2241	0.2707	0.2550	0.0145	-0.9000	-0.4580
2009	10	$a_{0,t}$	1.2509	1.2523	1.2517	0.0005	-0.5070	-0.9770
		$a_{1,t}$	-0.4592	-0.4580	-0.4585	0.0004	-0.5850	-1.1180
		$INDADSP_t$	0.5420	0.5888	0.5630	0.0144	0.0670	-0.1140
		$INDEXSP_t$	0.2509	0.2523	0.2517	0.0005	-0.5070	-0.9770

Table 2 Summary statistics of variables used in the regression analysis in the period 21 March 1995 through 10 March 2009

Variable[a]	Number of Weekly Observations	Mean	Standard deviation	Skewness	Excess Kurtosis
Panel A. Measures of speculation					
INDADSP	729	0.3061	0.1237	0.6959	-0.4825
INDEXSP	729	0.0703	0.0759	1.3205	0.6933
WOT	729	1.1613	0.1051	1.0879	0.1061
ADHEPR	729	0.0330	0.0243	0.8386	0.1101
ASSPPR	729	0.1214	0.1038	1.1325	0.9799
Panel B. Volatility Measures					
VOFT	729	0.0032	0.0024	3.1115	13.9503
VOST	729	0.0030	0.0028	6.0029	44.8618
Panel C. Control Variables					
PROD	729	5,748.5490	558.6112	-0.4605	-0.1103
STEXCSPR	729	310,616.2000	19,812.1500	-0.0067	-0.7189
STSPR	729	615,924.9000	57,385.6900	0.3978	-1.5390
NETIMP	729	10,503.0200	1,609.8950	-0.1692	-0.7161
INPREF	729	5,748.5490	558.6112	-0.4605	-0.1103

Note [a]
INDADSP is our measure of adequate speculation
INDEXSP is our measure of excessive speculation
WOT is Working's speculative index T
ADHEPR is the modified De Roon et. al.'s hedging pressure variable
ASSPPR is the modified Sanders et. al.'s speculative pressure variable
VOFT is the conditional variance of the futures return
VOST is the conditional variance of the spot return
PROD is the domestic production of crude oil in the U. S.
STEXCSPR is the ending stock of crude oil in the U. S. excluding the Strategic Petroleum Reserve
STSPR is the ending stock of crude oil in the U. S. within the Strategic Petroleum Reserve
NETIMP is the net import of crude oil into the U. S.
INPREF is the input of crude oil to refineries in the U. S.

Table 3 Results of the GARCH estimation of the conditional variance of the futures and spot return

	Estimate/t statistic Conditional variance of	
Model	**Futures return**	**Spot return**
μ	-0.000187	0.000104
	-0.1878	0.0821
w	0.000024	0.000079
	2.2734**	3.2267***
α	0.147070	0.106125
	8.0080***	6.8247***
β	0.862625	0.870670
	57.9560***	48.5782***
Number of weekly observations	1355	1212
Log Likelihood	2275.79	1920.26

Note
***statistically significant at the 99% confidence level
**   statistically significant at the 95% confidence level

Table 4 Results of the multiple regression analysis of the weekly futures price volatility on the weekly measures of speculation and fundamental factors over the period 21 March 1995 through 10 March 2009

This table shows the results of the regression analysis of the following equation:

$$VOFT_t = c_0 + c_1 * IND_t + c_2 * VOST_t + c_3 * PROD_t + c_4 * STEXCSPR_t + c_5 * STSPR_t + c_6 * NETIMP_t + c_7 * INPREF_t + \varepsilon_t$$

Where IND_t represents the measure of speculation/hedging in week *t*. *IND* is in turn *INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ASSPPR*, D_1, D_2, D_3, and D_4 are dummy variables with values=1 for sub-periods 2, 3, 4 and 5, respectively and 0 otherwise, and ε_t is the error term.

	Measure of speculation									
	INDADSP		***INDEXSP***		***WOT***		***ADHEPR***		***ASSPPR***	
Variable	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**
Constant	1.77E-03	1.0442	2.09E-03	1.2332	3.66E-04	0.1977	2.36E-03	1.3884	2.52E-03	1.4815
IND	4.12E-05	0.0591	2.73E-03	2.4339**	1.59E-03	1.8764*	-4.63E-03	-2.8465***	-1.35E-03	-3.0304***
VOST	7.70E-01	52.8528***	7.60E-01	51.3963***	7.63E-01	52.2185***	7.68E-01	54.1889***	7.66E-01	53.9365***
PROD	-1.59E-07	-0.9650	-1.75E-08	-0.1090	-4.48E-08	-0.2759	-1.85E-07	-1.2416	-1.56E-07	-1.0474
STEXCSPR	-9.86E-10	-0.4785	-1.88E-09	-0.9082	-1.44E-09	-0.7031	-6.32E-10	-0.3111	-4.73E-10	-0.2323
STSPR	-5.81E-09	-4.0294***	-7.98E-09	-5.2462***	-7.48E-09	-4.9040***	-6.28E-09	-5.1094***	-6.58E-09	-5.2879***
NETIMP	1.95E-08	0.3721	3.77E-08	0.7157	2.86E-08	0.5464	1.87E-08	0.3596	5.45E-10	0.0104
INPREF	2.43E-07	3.2613***	2.52E-07	3.4015***	2.44E-07	3.2854***	2.38E-07	3.2155***	2.39E-07	3.2271***
Adjusted R squared	0.8055		0.8071		0.8064		0.8076		0.8079	
Number of observations	729		729		729		729		729	

Note

***statistically significant at the 99% confidence level, ** statistically significant at the 95% confidence level, * statistically significant at the 90% confidence level

Table 5 Sub-periods used in the analysis, characteristics of sub-periods, and events causing changes in characteristics

Sub-period	Weekly observations for the period	Characteristics of sub-period	Event and date	Hypothesized effect on NYMEX crude oil futures contract	Hypothesized effect on measures of speculation
1	March 21, 1995 to December 21, 2000	Benchmark period			
2	After December 21, 2000 to November 13, 2002	Following granting of exemption to ICE from oversight by CFTC and exemption to swap dealers from speculative position limits	CFMA (2000) signed into law on December 21, 2000	Speculative activity expected to decrease Hedging activity expected to increase	*INDEXSP* and *WOT* expected to decrease *INDADSP*, *ADHEPR* and *ASSPPR* expected to increase
3	After November 13, 2002 to August 4, 2003	Following relaxation of rules for hedge funds under which they are exempt from CPO and CTA registrations	CFTC publishes Advance Notice of Proposed Rulemaking on November 13, 2002	Speculative activity expected to increase	*INDEXSP* and *WOT* expected to increase
4	After August 4, 2003 to February 3, 2006	Following granting of permission to bank holding companies to engage in an expanded range of commodity derivative activities	Federal Reserve publishes amendment to Regulation Y on August 4, 2003	Speculative activity and hedging activity are both expected to increase	*INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ADSPPR* expected to increase
5	After February 3, 2006 to March 10, 2009	Following initiation of trading of WTI crude oil futures on the ICE	The ICE begins trading WTI crude oil futures on February 3, 2006	Speculative activity expected to increase or decrease	*INDEXSP* and *WOT* expected to increase or decrease

Table 6 Variation of the measures of speculation over sub-periods 1 through 5

This table provides the results of a regression analysis of the following equation:

$$DEP_t = b_0 + b_1 * D_1 + b_2 * D_2 + b_3 * D_3 + b_4 * D_4 + \varepsilon_t$$

Where *DEP* is in turn *INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ASSPPR*, and D_1, D_2, D_3, and D_4 are dummy variables with values=1 for sub-periods 2, 3, 4 and 5, respectively and 0 otherwise, and ε_t is the error term.

	Dependent variable									
	INDADSP		***INDEXSP***		***WOT***		***ADHEPR***		***ASSPPR***	
Independent variable	Coefficient	t statistic	Coefficient	t statistic	Coefficient	t statistic	Coefficient	t statistic	Coefficient	t statistic
Constant	0.2004	69.9527***	0.0149	5.3665***	1.0778	439.1635***	0.0340	24.8004***	0.1727	33.9983***
D_1	0.0718	12.4228***	0.0210	3.7403***	0.0400	8.0785***	0.0095	3.4244***	-0.0144	-1.4089
D_2	0.0906	10.4606***	0.0279	3.3258***	0.0649	8.7499***	-0.0050	-1.2005	-0.0762	-4.9625***
D_3	0.1477	28.3925***	0.0675	13.3827***	0.1109	24.8779***	0.0001	0.0241	-0.0878	-9.5238***
D_4	0.2922	60.3472***	0.1751	37.2663***	0.2469	59.5170***	-0.0088	-3.8121***	-0.1337	-15.5665***
Adjusted R squared	0.8386		0.6676		0.8357		0.0451		0.2793	
Number of observations	729		729		729		729		729	

Note

*** statistically significant at the 99% confidence level, **statistically significant at the 95% confidence level, * statistically significant at the 90% confidence level

Table 7 Results of the multiple regression analysis of the weekly futures price volatility on the weekly measures of speculation and fundamental factors over the period 21 March 1995 through 10 March 2009

This table shows the results of the regression analysis of the following equation:

$$VOFT_t = c_0 + c_1 * IND_t + c_2 * D_1 * IND_t + c_3 * D_2 * IND_t + c_4 * D_3 * IND_t + c_5 * D_4 * IND_t + c_6 * VOST_t + c_7 * PROD_t + c_8 * STEXCSPR_t + c_9 * STSPR_t + c_{10} * NETIMP_t + c_{11} * INPREF_t + \varepsilon_t$$

Where IND_t represents the measure of speculation/hedging in week *t*. *IND* is in turn *INDADSP*, *INDEXSP*, *WOT*, *ADHEPR* and *ASSPPR*, D_1, D_2, D_3, and D_4 are dummy variables with values=1 for sub-periods 2, 3, 4 and 5, respectively and 0 otherwise, and ε_t is the error term.

	Measure of speculation									
	INDADSP		***INDEXSP***		***WOT***		***ADHEPR***		***ASSPPR***	
Variable	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**	**Coefficients**	**t statistics**
Constant	3.20E-03	1.3981	1.84E-03	1.0230	-1.88E-03	-0.6992	1.08E-03	0.5886	1.01E-03	0.5400
IND	-2.74E-04	-0.2298	1.79E-02	3.0597***	4.51E-03	3.9008***	-8.02E-03	-3.5759***	-1.81E-03	-3.6157***
D_1*IND*	1.10E-04	0.1705	-1.07E-02	-1.9416*	-2.89E-04	-2.0436**	6.17E-03	2.1313**	9.22E-04	1.2157
D_2*IND*	2.17E-03	2.2085**	-6.84E-03	-0.9979	2.09E-04	0.9419	2.04E-02	3.5803***	5.44E-03	3.3899***
D_3*IND*	1.55E-03	1.3308	-1.14E-02	-1.7517	1.76E-05	0.0570	7.78E-03	2.0985**	1.82E-03	1.4503
D_4*IND*	9.66E-04	0.8661	-1.46E-02	-2.4098**	-5.05E-04	-1.4746	-4.86E-03	-1.1125	-7.22E-03	-2.9673***
VOST	7.66E-01	52.1038***	7.61E-01	51.3426***	7.61E-01	52.8906***	7.64E-01	54.3918***	7.60E-01	54.1136***
PROD	-2.14E-07	-1.2716	-5.01E-08	-0.3011	-1.34E-07	-0.7991	-2.53E-07	-1.5900	-2.40E-07	-1.5018
STEXCSPR	2.80E-09	1.0971	-1.71E-09	-0.7153	2.89E-09	1.1466	5.04E-09	2.0660**	5.74E-09	2.3186**
STSPR	-8.73E-09	-2.9872***	-7.67E-09	-3.6324***	-1.00E-08	-3.1227***	-5.05E-09	-3.3257***	-5.27E-09	-3.4333***
NETIMP	-2.90E-08	-0.5025	1.67E-08	0.3130	1.92E-08	0.3376	-5.38E-08	-0.9579	-5.13E-08	-0.9062
INPREF	2.35E-07	3.1669***	2.66E-07	3.5966***	2.35E-07	3.1703***	2.34E-07	3.2033***	2.30E-07	3.1509***
Adjusted R squared	0.8092		0.8123		0.8178		0.8199		0.8207	
Number of observations	729		729		729		729		729	

Note

***statistically significant at the 99% confidence level, ** statistically significant at the 95% confidence level, * statistically significant at the 90% confidence level

Table 8 Results of the Granger Causality Tests of whether the measure of speculation causes the crude oil futures price volatility or the crude oil futures price volatility causes the measure of speculation over the period 21 March 1995 through 10 March 2009

		Coefficient/t statistic				
Number	**Null Hypotheses**	e_{11}	e_{12}	e_{13}	e_{14}	**F value**
	Measure of speculation does not Granger cause the futures price volatility					
1	Null: *INDADSP* does not Granger cause *VOFT*	-0.0002	0.0013	-0.0037	0.0030	1.4963
		-0.1101	0.5776	-1.7369*	2.0004**	
2	Null: *INDEXSP* does not Granger cause *VOFT*	-0.0015	0.0001	0.0011	0.0004	1.0060
		-1.1102	0.0644	0.0015	0.0004	
3	Null: *WOT* does not Granger cause *VOFT*	-0.0030	-0.0001	0.0029	0.0006	1.2129
		-1.1964	-0.0240	0.8897	0.2321	
4	Null: *ADHEPR* does not Granger cause *VOFT*	-0.0011	0.0025	-0.0049	0.0031	0.7181
		-0.4757	0.7947	-1.5662	1.3482	
5	Null: *ASSPPR* does not Granger cause *VOFT*	0.0002	0.0000	-0.0013	0.0010	0.9902
		0.3405	-0.0019	-1.6193	1.6529*	
Number	**Null Hypotheses**	e_{21}	e_{22}	e_{23}	e_{24}	**F value**
	The futures price volatility does not Granger cause the measure of speculation					
6	Null: *VOFT* does not Granger cause *INDADSP*	-0.3097	-1.5052	1.6722	0.3868	1.3580
		-0.3389	-1.1490	1.2748	0.4143	
7	Null: *VOFT* does not Granger cause *INDEXSP*	-0.5359	3.0682	-3.2603	1.2328	2.0404*
		-0.5227	2.0937**	-2.2191**	1.1798	
8	Null: *VOFT* does not Granger cause *WOT*	-0.2232	1.6627	-1.9266	0.7101	2.0432*
		-0.3976	2.0734**	-2.3963**	1.2415	
9	Null: *VOFT* does not Granger cause *ADHEPR*	-0.3868	-1.0506	1.3373	0.0750	1.5672
		-0.6367	-1.2054	1.5323	0.1208	
10	Null: *VOFT* does not Granger cause *ASSPPR*	-0.5368	-4.7460	3.8139	1.0207	1.4047
		-0.2287	-1.4105	1.1315	0.4257	

Note
***statistically significant at the 99% confidence level, ** statistically significant at the 95% confidence level, * statistically significant at the 90% confidence level

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